

CLAIMS

1. A method for determining the location of a mobile terminal (112; 500) in a cellular communication network (110), the mobile terminal being provided with means for receiving signals from satellites (132) of a satellite-based positioning system (130), comprising the steps of:

5 receiving, at the mobile terminal, signals from a plurality of satellites;

measuring, at the mobile terminal, pseudoranges to the satellites at time of signal reception;

10 calculating (S2; S4') the location of the mobile terminal based on parameters representing the measured pseudoranges;

determining a quality measure associated with the location calculation;

comparing (S3; S5) the determined quality measure to a first predefined quality criterion; and

15 recalculating (S4; S4'; S4-1; S4-1'; S6), if the quality measure does not fulfil the first predefined quality criterion, the location of the mobile terminal with added correction for errors in at least one parameter representing a parameter measured at the mobile terminal.

20 2. The method of claim 1, wherein the added correction of said recalculating step (S4; S4'; S4-1; S4-1'; S6) involves correction for errors in a parameter representing a time of signal reception at the mobile terminal and/or a parameter representing at least one of the measured pseudoranges.

25 3. The method of claim 2, wherein said calculating step (S2) uses a parameter for time of signal reception measured at the mobile terminal (112; 500) and said recalculating step (S4'; S4-1'; S6) involves correction for errors in this parameter by using a transmission time offset parameter as an additional unknown parameter.

30 4. The method of claim 3, further comprising the steps of:
determining a quality measure associated with the location recalculation of said recalculating step (S4'; S4-1');

comparing (S5; S4-2') the determined quality measure of the recalculation with a second predefined quality criterion; and

5 performing, if the quality measure does not fulfil the second predefined quality criterion, a second recalculation (S6; S4-3') of the location of the mobile terminal in an iterative calculation procedure for pseudorange outlier correction.

10 5. The method of claim 2, wherein said calculating step (S2) uses a parameter for time of signal reception measured at the mobile terminal (112; 500) and said recalculating step (S4; S4-1; S6) involves correction for errors in the pseudoranges measured at the mobile terminal (112; 500) through an iterative calculation procedure for pseudorange outlier correction.

15 6. The method of claim 5, further comprising the steps of:

determining a quality measure associated with the location recalculation of said recalculating step (S4; S4-1);

comparing (S5; S4-2) the determined quality measure of the recalculation with a second predefined quality criterion; and

20 performing, if the quality measure does not fulfil the second predefined quality criterion, a second recalculation (S6; S4-3) of the location of the mobile terminal with correction for errors in the time of signal reception by using a transmission time offset parameter as an additional unknown parameter.

25 7. The method of claim 4 or 6, further comprising the steps of:

determining a quality measure associated with the second recalculation (S4-3; S4-3');

comparing (S5) the determined quality measure of the second recalculation with a third predefined quality criterion; and

30 performing, if the quality measure does not fulfil the third predefined quality criterion, a third recalculation (S6) of the location of the mobile terminal with the correction using the transmission time offset parameter as an additional unknown parameter in combination with the correction for

errors through the iterative calculation procedure for pseudorange outlier correction.

8. The method of claim 4 or 5, wherein said iterative calculation procedure for pseudorange outlier correction involves location computations using a transmission time offset parameter as an additional unknown parameter for correction for errors in the parameter representing the time of signal reception.

10 9. The method of claim 2, wherein said calculating step (S4') uses a transmission time offset parameter as an additional unknown parameter and said recalculating step (S6) involves correction for errors in at least one representative of the pseudoranges measured at the mobile terminal (112; 500) using the transmission time offset parameter in an iterative calculation 15 procedure for pseudorange outlier correction.

10. The method of any of claims 4-9, wherein the iterative calculation procedure for pseudorange outlier correction (S6; S4-1; S4-3') in turn involves the steps of:

20 computing (S6-1) the location of the mobile terminal repeatedly, omitting one pseudorange measurement at a time;

determining (S6-2) a quality measure associated with each computed location;

25 evaluating (S6-4, S6-5, S6-7) the determined quality measures, whereby a comparatively high quality is an indication that the omitted pseudorange is an outlier; and

removing, if an outlier pseudorange was detected in the evaluating step, the outlier pseudorange and using the location computed with the outlier pseudorange omitted as mobile terminal location (S6-6).

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11. The method of any of previous claims, wherein the transmission time offset parameter represents the time difference between the time of signal

transmission from the respective satellites (132) and the network time of the satellite-based positioning system (130).

12. The method of any of previous claims, wherein the quality measure is a 5 measure of the parameter estimate quality determined using the residual of a least squares solution for the mobile terminal location.

13. The method of any of previous claims, further comprising the step of 10 reconstructing, in case at least one of the measured pseudoranges is a truncated pseudorange, a complete pseudorange from the truncated pseudorange based on a parameter for time of signal reception at the mobile terminal (112; 500) and an approximate mobile terminal location.

14. The method of any of previous claims, wherein the respective steps of 15 calculating and recalculating in turn comprises the steps of:

defining a nonlinear equation system with unknown parameters at least for the mobile terminal location and the mobile terminal clock bias;
linearizing the equation system such that the satellite motion is modeled as linear with a nominal satellite position and a velocity vector; and
20 solving the equation system for the mobile terminal location.

15. The method of claim 14, comprising:

determining the nominal position for the respective satellites (132) 25 using a time of satellite transmission determined based on a measured pseudorange and a parameter for time of signal reception at the mobile terminal (112; 500); and

expressing the satellite position in a local tangential coordinate system with two horizontal and one vertical coordinate.

30 16. A mobile terminal (112; 500) in a cellular communication network (110), the mobile terminal being provided with means for determining its location, comprising:

means (510, 512) for receiving signals from a plurality of satellites (132) of a satellite-based positioning system (130);

means (520) for measuring pseudoranges to the satellites at time of signal reception;

5 means (522) for calculating the location of the mobile terminal based on parameters representing the measured pseudoranges;

means for determining a quality measure associated with the location calculation;

10 means for comparing the determined quality measure to a first predefined quality criterion; and

means for recalculating, if the quality measure does not fulfil the first predefined quality criterion, the location of the mobile terminal with added correction for errors in at least one parameter representing a parameter measured at the mobile terminal.

15 17. The mobile terminal of claim 16, wherein said means for calculating is adapted for using a parameter for time of signal reception measured at the mobile terminal (112; 500) and said means for recalculating involves means for correction for errors in this parameter through a transmission time offset
20 parameter as an additional unknown parameter.

18. The mobile terminal of claim 17, further comprising:

means for determining a quality measure associated with the location recalculations;

25 means for comparing the determined quality measure of the recalculations with a second predefined quality criterion; and

means for a second recalculations, if the quality measure does not fulfil the second predefined quality criterion, of the location of the mobile terminal (112; 500) involving means for iterative pseudorange outlier correction.

30 19. The mobile terminal of claim 16, wherein said means for calculating is adapted for using a parameter for time of signal reception measured at the mobile terminal (112; 500) and said means for recalculating involves means

for correction for errors in the pseudoranges measured at the mobile terminal (112; 500) through iterative pseudorange outlier correction.

20. The mobile terminal of claim 19, further comprising:

- 5 means for determining a quality measure associated with the location recalculation;
- means for comparing the determined quality measure of the recalculation with a second predefined quality criterion; and
- means for a second recalculation, if the quality measure does not fulfil the second predefined quality criterion, of the location of the mobile terminal (112; 500) with correction for errors in the time of signal reception through a transmission time offset parameter as an additional unknown parameter.

21. The mobile terminal of claim 18 or 20, further comprising:

- 15 means for determining a quality measure associated with the second recalculation;
- means for comparing the determined quality measure of the second recalculation with a third predefined quality criterion; and
- means for a third recalculation of the location of the mobile terminal, in case the quality measure does not fulfil the third predefined quality criterion, said third recalculation comprising the correction for errors through the transmission time offset parameter in combination with the iterative pseudorange outlier correction.

25 22. The mobile terminal of claim 18 or 19, wherein said iterative pseudorange outlier correction involves means for location computations with a transmission time offset parameter as an additional unknown parameter.

30 23. The mobile terminal of claim 16, wherein said means for calculating is adapted for using a transmission time offset parameter as an additional unknown parameter and said means for recalculating involves means for correction for errors in at least one representative of the pseudoranges

measured at the mobile terminal (112; 500) using the transmission time offset parameter in iterative pseudorange outlier correction.

24. The mobile terminal of any of claims 18-23, comprising means for iterative calculation with pseudorange outlier correction that in turn includes:

5 means for repeatedly computing the location of the mobile terminal (112; 500), omitting one pseudorange measurement at a time;

means for determining a quality measure for each computed location;

means for evaluating the determined quality measures, whereby a

10 comparatively high quality is an indication that the omitted pseudorange is an outlier; and

means for removing, if an outlier pseudorange was detected by the evaluating means, the outlier pseudorange, whereby the location computed with the outlier pseudorange omitted is used as mobile terminal location.

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25. The mobile terminal of any of claims 16-24, wherein the quality measure is based on the residual of a least squares solution for the mobile terminal location.

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26. The mobile terminal of any of claims 16-25, further comprising means for reconstructing a complete pseudorange from a measured truncated pseudorange based on a parameter for time of signal reception at the mobile terminal (112; 500) and an approximate mobile terminal location.

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27. A positioning node (117) in a cellular communication network (110) with means for determining the location of a mobile terminal (112; 500) in the cellular communication network, the mobile terminal being provided with means for receiving signals from satellites (132) of a satellite-based positioning system (130), comprising:

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means for receiving, from the mobile terminal, parameters relating to measured pseudoranges to a plurality of satellites, the pseudoranges relating to the time of measurement;

means for calculating the location of the mobile terminal based on parameters representing the measured pseudoranges;

means for determining a quality measure associated with the location calculation;

5 means for comparing the determined quality measure to a first predefined quality criterion; and

means for recalculating, if the quality measure does not fulfil the first predefined quality criterion, the location of the mobile terminal with added correction for errors in at least one parameter representing a parameter 10 measured at the mobile terminal.

28. The positioning node of claim 27, wherein said means for calculating is adapted for using a parameter for time of signal reception reported by the mobile terminal (112; 500) and said means for recalculating involves means 15 for correction for errors in this parameter through a transmission time offset parameter as an additional unknown parameter.

29. The positioning node of claim 28, further comprising:

means for determining a quality measure associated with the location 20 recalculations;

means for comparing the determined quality measure of the recalculations with a second predefined quality criterion; and

means for a second recalculations, if the quality measure does not fulfil the second predefined quality criterion, of the location of the mobile terminal (112; 25 500) involving means for iterative pseudorange outlier correction.

30. The positioning node of claim 27, wherein said means for calculating is adapted for using a parameter for time of signal reception measured at the mobile terminal (112; 500) and said means for recalculating involves means 30 for correction for errors in the pseudoranges measured at the mobile terminal (112; 500) through iterative pseudorange outlier correction.

31. The positioning node of claim 30, further comprising:

means for determining a quality measure associated with the location recalculation;

means for comparing the determined quality measure of the recalculation with a second predefined quality criterion; and

5 means for a second recalculation, if the quality measure does not fulfil the second predefined quality criterion, of the location of the mobile terminal (112; 500) with correction for errors in the time of signal reception through a transmission time offset parameter as an additional unknown parameter.

10 32. The positioning node of claim 29 or 31, further comprising:

means for determining a quality measure associated with the second recalculation;

means for comparing the determined quality measure of the second recalculation with a third predefined quality criterion; and

15 means for a third recalculation of the location of the mobile terminal, in case the quality measure does not fulfil the third predefined quality criterion, said third recalculation comprising the correction through the transmission time offset parameter in combination with the iterative pseudorange outlier correction.

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33. The positioning node of claim 29 or 30, wherein said iterative pseudorange outlier correction involves means for location computation with a transmission time offset parameter as an additional unknown parameter.

25 34. The positioning node of claim 27, wherein said means for calculating is adapted for using a transmission time offset parameter and said means for recalculating involves means for correction for errors in at least one representative of the pseudoranges measured at the mobile terminal (112; 500) using the transmission time offset parameter in iterative pseudorange 30 outlier correction.

35. The positioning node of any of claims 29-34, comprising means for iterative calculation with pseudorange outlier correction that in turn includes:

means for repeatedly computing the location of the mobile terminal (112; 500), omitting one pseudorange measurement at a time;

means for determining a quality measure for each computed location;

5 means for evaluating the determined quality measures, whereby a comparatively high quality is an indication that the omitted pseudorange is an outlier; and

means for removing, if an outlier pseudorange was detected by the evaluating means, the outlier pseudorange, whereby the location computed with the outlier pseudorange omitted is used as mobile terminal location.

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36. The positioning node of any of claims 27-35, wherein the quality measure is based on the residual of a least squares solution for the mobile terminal location.

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37. The positioning node of any of claims 27-36, further comprising means for reconstructing a complete pseudorange from a measured truncated pseudorange based on a parameter for time of signal reception at the mobile terminal (112; 500) and an approximate mobile terminal location.

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38. A communication system with means for determining the location of a mobile terminal (112; 500) in a cellular communication network (110), the mobile terminal being provided with means for receiving signals from satellites (132) of a satellite-based positioning system (130), comprising the positioning node (117) of any of claims 27-37.
